Part

B

Methods and Assumptions for Calculating the LTSY Projections

-- SECTION 1 - SUSTAINED YIELD PLANNING PROCESS OVERVIEW

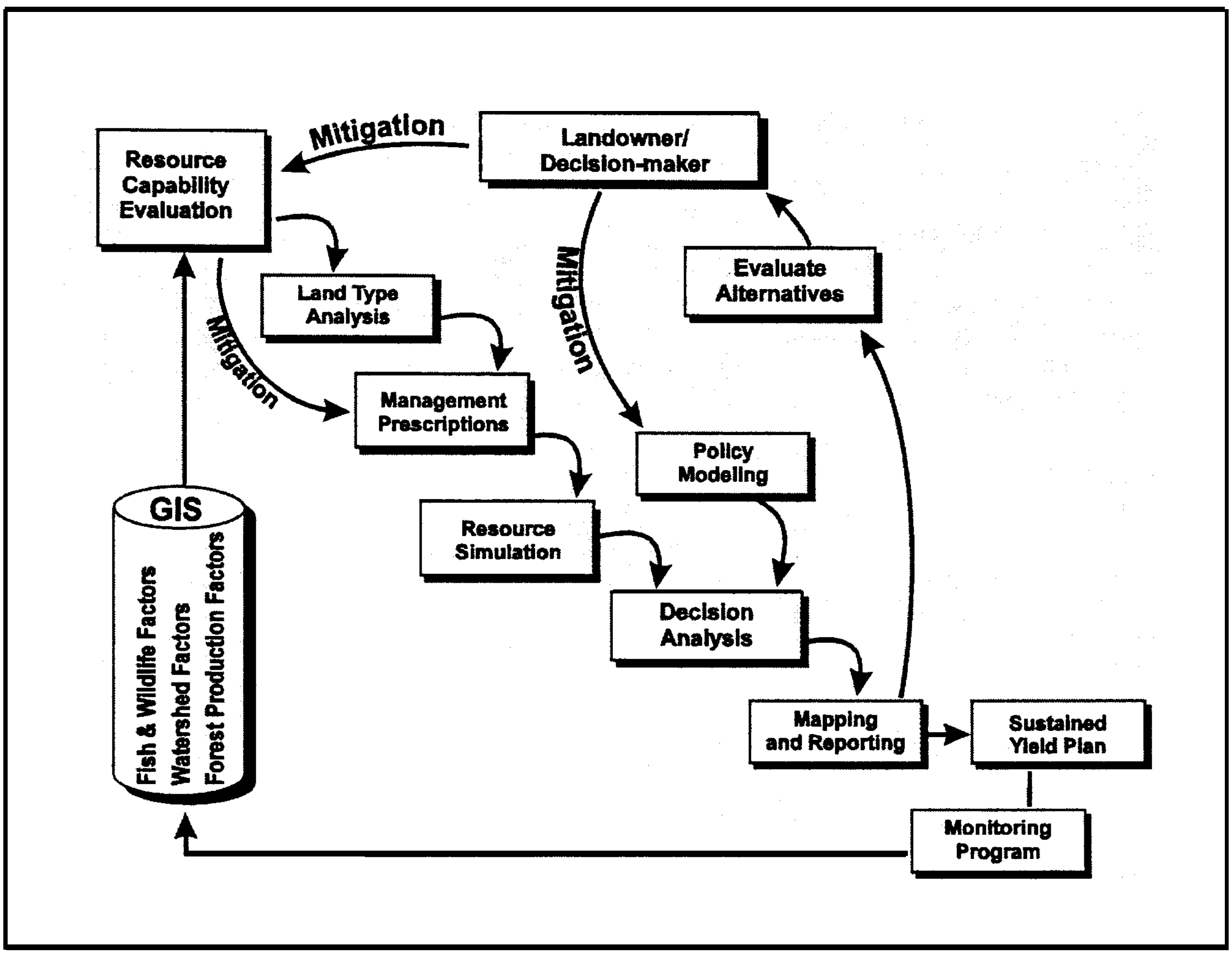
Introduction

The process through which The Pacific Lumber Company (PALCO) has developed and selected a management plan is comprehensive, rigorous, and scientifically based. PALCO's sustained yield planning process (as depicted in Figure l-1) has allowed PALCO to optimize the mix of management prescriptions across the landscape to meet the diverse and often conflicting management goals established for this management unit and to evaluate trade-offs among the alternatives. This document describes the sustained yield planning process through which PALCO has selected a management strategy that will be implemented over the next decade and beyond.

Sustained Yield Planning Approach

Developing an approach to sustained yield planning that integrates the assessment of timber, fish and wildlife, and watershed resources within a single analysis framework was one of the earliest and most difficult challenges facing PALCO. Figure l-l and the descriptions that follow provide a brief overview of PALCO's unique and innovative approach to developing and monitoring a sustained yield plan for its forestlands.

The sustained yield planning process is the mechanism through which PALCO examines the ecological capabilities of its lands, develops objectives and strategies for managing these lands, prescribes management practices, and evaluates and monitors the long-term trends of the practices implemented across the landscape.



The Foundation: A GIS Database

PALCO's comprehensive geographic information system (GIS) and related resource inventory databases are the foundation of the planning process. The GIS database contains spatial and descriptive characteristics of the diverse biophysical environments found on company lands. Information about a full range of resources is maintained in the GIS. This information is used in virtually all aspects of the sustained yield planning process and also allows management prescriptions to be implemented and monitored on a site-specific basis.

Resource Capability Evaluation

Existing wildlife, fish, watershed, and other resources are characterized and sensitivities identified at several levels of resolution: the landscape level, the watershed level, and the site-specific level. The information generated is used to help formulate policies that are used in PALCO's sustained yield planning process, to create meaningful analysis units (land types), to specify management goals, and to appropriately constrain land uses. All of this information directly affects the timing and mix of on-the-ground operations.

The analysis and policy-making that occur as a part of this effort is iterative in nature. In fact, one of the most unique and powerful features of PALCO's sustained yield planning process is the way in which unacceptable impacts of alternative management scenarios can be evaluated and, through successive refinement of policies, mitigated; the effect is that mitigation is built into the planning process. Using this iterative process, PALCO has formulated management policies that result in desirable levels of protection for sensitive resources while achieving maximum sustainable production of high-quality forest products.

Land Type Analysis

Land types are the basic landscape units for which alternative management regimes are evaluated over time. Land types have four basic components: planning watersheds, vegetation class, site productivity, and special concern areas. The GIS is used to combine these components into meaningful units that can be mapped and managed over time.

Management Prescriptions

PALCO's forestlands represent a set of existing conditions that reflect the past management history and productive capacity. A wide range of alternative silvicultural regimes have been developed that can be feasibly applied to the diversity of land types. Regimes are designed to maintain or improve the yield of forest products while still protecting fish, wildlife, and watershed resources.

Resource Simulation

Forest-product yields are generated using forest growth and yield models. Wildlife habitat relationships (WHR) are also derived as are a number of other forest inputs and outputs for each management prescription on each land type under consideration. These models have been integrated into a single computer simulator that makes it feasible to examine large numbers of complex management prescriptions.

The result of these simulations create what is called a resource capability model (RCM). The RCM represents the biophysical response of the forest to a wide range of management options. Many of the options may not be legally, politically, environmentally, or economically viable, but they are included to provide a context for the option ultimately chosen.

Policy Modeling

PALCO must establish goals and objectives for a given forest area and must respond to a variety of public issues, regulations, and concerns in selecting a set of policies regarding the management of this land. Establishing objectives, goals for desired future conditions, and constraints to management activities is really the central task in the sustained yield planning process. The policy formulation is actually considered independently from the RCM in order to allow maximum flexibility in examining the implications of all policy options.

Decision Analysis

The various yields produced through the 120-year planning horizon by each of the management prescriptions contained within the RCM, together with the available acreage of each land type, are loaded into a linear programming matrix. Similarly, management objectives and operational and environmental constraints are included in the matrix from the policy model. This matrix is used as input to the linear programming software that, when run, produces a solution.

The linear programming solution allocates land uses over time (land use allocation). That is, it optimizes the number of acres allocated to each management prescription on each land type relative to the specified management and environmental objectives and constraints. It is largely through this process that a balance is struck between maximum sustained timber production and other resource values.

Mapping and Reporting

After a linear programming decision model has been solved, the results must be examined in detail to fully determine the implications of a given management scenario. The linear programming solution contains the acreage of selected silvicultural prescriptions for each land type in the management unit. This solution is linked to the GIS to facilitate thorough spatial and tabular reporting. Maps and reports (graphical and tabular) are produced for each Watershed Assessment Area (WAA) and for the management unit as a whole to help interdisciplinary assessment teams consistently interpret the results of the management scenario.

Evaluation of Alternatives

The long-term implications and trends of timber, fish, wildlife, and watershed resources from the selected mix of management prescriptions are determined for each WAA. If product outputs are too low or impacts are too great, the resource sensitivities can be reevaluated, policies altered, and the decision analysis can be re-run with modified constraints. Through this iterative process, amounts and locations of management prescriptions that potentially result in adverse impacts are identified and mitigated. When a balanced land use allocation is found, detailed assessments describing both short-term and long-term cumulative impacts and resource trends are prepared.

Sustained Yield Plans

The principal product resulting from this process is a sustained yield plan for each management unit on PALCO’s forestlands. In addition, the management plan is prepared with an eye toward developing appropriate choices of silvicultural prescriptions and resource protection measures to serve as the basis for habitat conservation plans (HCPs).

Monitoring Program

The monitoring program is an important component of the SYP both for tracking the implementation and for assessing the long-term effectiveness of the plan. Field monitoring and data collection procedures will be integrated with the GIS to ensure that the best available data is used for future plan revisions. Continued iterative use of PALCO’s sustained yield planning approach will ensure effective adaptive management strategies are developed. This is particularly important because many of the elements of the SYP are based on models and data sets that were not originally designed to support long (i.e., 100-year) planning horizons.

SECTIONS-LAND TYPE ANALYSIS

Introduction

The objective of the land type analysis is to develop GIS data sets that contain logical and reasonable aggregations of land conditions that exist across PALCO's ownership. Land types are spatially explicit land units to which management activities are allocated over time. Selecting the mix of management activities that are scheduled to occur on each land type is accomplished through a linear programming land allocation process that is discussed further in the Section 5 - Land Allocation. A land condition must be considered to be land type component if that condition (1) affects the expected future conditions that result from a time series of management activities, (2) affects the range of management activities that could be applied to the land type, (3) affects the amount, timing, or cost of any specific management activity that may be applied to it, and/or (4) must be reported on as a part of the final SYP documentation.

The land type process actually has two phases: (1) creation of strum types, the basic land units for computation of growth and yield predictions, and (2) creation of land types, the basic land unit to which management activities are allocated and scheduled over time.

Creating Strata Types

Strata types are the basic land units for which growth and yield predictions are made. Strata types are created through a GIS overlay and generalization process that combines forest vegetation strata polygons with site quality polygons, resulting in a 6 acre minimum mapping unit (polygon) size. There are cases, such as areas adjacent to ownership boundaries, where individual polygons may actually be less than 6 acres to preserve important analysis boundaries.

After strata type polygons are created within the GIS, a series of data tables are created to control the growth and yield processing, facilitate tracking of growth and yield estimates through the linear programming land allocation process, and to link the linear programming solution back to the GIS and relational database for subsequent reporting and analysis:

SDX--the Strata type Description exchange file is an ASCII file that is required by the FREIGHTS simulator and contains information needed to control growth and yield processing.

ST--the strata type file is an ASCII file that is imported into the *resource capability model* (RCM) database, and contains information that is needed to relate strata types to their appropriate growth and yield estimates for creation of the linear programming decision analysis matrix and for detailed reporting and analysis. The ST and SDX files contain the same information, but are written in different formats.

PCX--the Plot Control exchange file, a dBase file that contains information for assigning site index values and extracting the appropriate plots and tree list data from PALCO's forest resource inventory database for each strata type.

UDL--the UpDate Length file is an ASCII file used by FREIGHTS that contains information regarding the length in years that a set of plots must be grown (to update their tree dimensions) to assure that all plot data used in growth and yield simulations begin from the same relative starting date.

Approximately 7% of PALCO's timberlands are covered by currently approved, active, or planned timber harvesting plans (collectively referred to as active THPs). Subsequent to the strata type processing associated with existing vegetation strata and site combinations described above, another set of processing steps is conducted for creating a set of strata types that define current THPs. The processing steps follow a similar logical order of GIS overlay processing and generalization to a 6 acre minimum polygon size, and then create the same series of data tables listed above to control growth and yield processing and relational database processing and reporting for active THPs.

The computer programs for creating strata types are available from VESTRA Resources. Inc. (VESTRA) for review, and are considered proprietary information. These routines are written in ARC/INFO AML (ARC Macro Language).

Creating Land Types

Land types are the basic land units to which management activities are allocated and scheduled over time. Land types have the following basic components:

Strata type--the combination of vegetation strata, site quality, and active THPs as described above

Yarding method--tractor, cable, or helicopter

Watershed assessment areas

Special concern areas--such as WLPZs, Wild and Scenic River buffer areas

The GIS is used to combine these land type components into meaningful units that can be managed over time. There are usually multiple polygons for a given land type. A valid land type is defined by the unique combination of all of its land type components.

Land types are created using GIS overlay analysis. Because of the various independent data layers used to create land types, many very small polygons can result. Small polygons (less than 0.5 acres) are first aggregated into neighboring polygons. These polygons are then generalized to produce a minimum polygon size of 6 acres using the following rules: (1) yarding method and site class boundaries will not split vegetation polygons, (2) yarding method and site class boundaries will not split THP boundaries, and (3) features such as special concern areas which are inherently small, and features such as ownership and watershed assessment areas whose boundaries must remain constant are processed such that the GIS will not eliminate their borders. This processing logic does result in polygons that are as small as 0.5 acres, but only in cases where the modeling or analysis requires these small but important areas to be preserved.

It is also possible for land type polygons to be quite large. The processing procedures allow large polygons to be subdivided by logical breaks such as slope, aspect, and road crossings to produce polygons that are no larger than 40 acres. This helps ensure that individual land units do not exceed legal size limitations and will more likely conform to operational units to be included in future THPs.

After the GIS overlay and generalization processing, an ASCII file referred to as the LMX (Land type Model exchange) file is produced. This file is imported into the RCM database and contains pertinent information about each land type that is needed to link strata type yields to land type polygons for the linear programming decision analysis and other reporting and analyses.

The computer programs for creating land types are available from VESTRA for review, and are considered proprietary information. These routines are written in ARC/INFO AML (ARC Macro Language).

Land Type Data Sources

The table below lists PALCO's land type data layers and their origins.

Table 1. Land Type Data Sources

Data Layer	Data Source
Land Type Base Components:	
Ownership boundary	PALCO
Vegetation strata	PALCO
Site quality	Based on soil-vegetation maps of California (PSW Forest Range and Experiment Station in cooperation with University of California, 1961, Humboldt County Area)
Watershed assessment areas	PALCO--derived from CDF Calwater database
Active THPs	PALCO
Yarding method	Modeled from slope classes generated from USGS 7½' quad contour data
Land Type Special Concern Components:	
WLPZ (stream buffers)	Generated via GIS; Class I WLPZ buffers of 30', 100' and 170', Class II WLPZ buffers of 10' and 100'
Old growth buffers	PALCO - Buffers of approximately 300' adjacent to old growth on non-PALCO land.
Marbled murrelet conservation areas	PALCO
Ownership by PL company	PALCO
Park neighbor buffers	200' buffer of ownership boundary lines shared with State parks
Wild and scenic river buffers	200' buffer of wild and scenic rivers
Public road buffers	200' buffer of public roads

Site Quality

In the site quality GIS layer, PALCO's lands are attributed as site 1, 2 or 3 (forestland appropriate for timber growth and management), site 8 (forestland of poor timber growth potential and frequently dominated by hardwoods - to be maintained as wildlife habitat) or site 9 (non-forestland - water, rock, prairie, etc.). Each site quality type has associated with it a site index value which is used in the yield generation modeling process to control the modeled tree growth. The following table displays the SO-year site index values used for each tree species found on PALCO lands. No tree growth modeling occurred on lands identified as 'site 9'.

Species	Site 1	Site 2	Site 3	Site 8
DF - Douglas Fir	141	120	99	46
RW - Redwood	117	100	83	40
GF - Grand Fir	141	120	99	46
HL - Hemlock	113	96	79	36
RC - Red Cedar	141	120	99	46
SS - Sitka Spruce	141	120	99	46
OR - Old Gr. Douglas Fir	102	86	71	33
RR - Old Gr. Redwood	102	86	71	33
AL - Alder	113	96	79	36
BL - Bay Laurel	56	48	40	18
MO - Madrone	56	48	40	18
TO - Tanoak	87	74	61	28
HD - Other Hardwoods	56	48	40	18

Fifty-year site index values for redwood and Douglas fir on site 2 lands (100 and 120, respectively) were derived from PALCO site tree data. These values are the basis for the majority of the growth modeling effort, as redwood and Douglas fir are the dominant tree species on PALCO land and approximately 91% of PALCO lands are classified as site 2. Redwood and Douglas-fir 50-year index values for sites 1 and 3 were estimated as being 17% higher (for Site 1) or 17% lower (for site 3) than the site 2 indices; these estimates are based on a conservative interpretation of Watson, Krumland and Wensel (Co-op Redwood Yield Research Note Number 10, Conversions for Site Index Systems used in the North Coast of California, 4/30/79). Site 8 index values were estimated to be 40% of site 2 values.

Fifty-year site indices for species other than redwood and Douglas fir were estimated as a percentage of Douglas fir site values. The percentages were based on comparative values of site from a data set derived from the 1978-82 USFS Forest Survey of California.
Percentages for the various species were

- Grand fir, red cedar, sitka spruce - 100%
- Hemlock, alder - 80%
- Old growth redwood, old growth Douglas fir - 72%
- Tanoak - 62%
- Bay laurel, madrone, other hardwoods - 40%.

Section 3 - Silvicultural Prescriptions

Introduction

Approximately 170 silvicultural prescriptions were considered for each of PALCO's strata types. A silvicultural prescription is a combination of silvicultural treatments applied in specific decades. In order to describe these prescriptions in a more expedient manner, they have been grouped into silvicultural regimes. A silvicultural regime is a set of silvicultural prescriptions that begin in different decades. For example, one of PALCO's silvicultural regimes consists of the following prescriptions:

1) Clearcut, 50-year rotation, extensive management, begin in decade 1

2) Clearcut, 50-year rotation, extensive management, begin in decade 2

3) Clearcut, 50-year rotation, extensive management, begin in decade 3

4) Clearcut, 50-year rotation, extensive management, begin in decade 4

5) Clearcut, 50-year rotation, extensive management, begin in decade 5

6) Clearcut, 50-year rotation, extensive management, begin in decade 6

Regime Descriptions

No Harvest

Regime Codes 1

Description Stands will be grown for 12 decades without any harvesting.

Regime Trigger Condition Stands of all stocking levels are eligible for this regime

Restocking

Regime Codes 11-16

Starting Decades for the Regime

Regime Code	11	12	13	14	15	16
Starting Decade	1	***2***	***3***	***4***	***5***	***6***

Description This regime is intended to restock lands which are potentially productive timberland, but currently have no trees on them. Approximately 400 trees/acre are planted and managed intensively; i.e.- site preparation, planting of improved seedlings, competing vegetation control and pre-commercial thinning treatments are applied. A commercial thin is scheduled for 60 years after restocking; this harvest has a residual basal area of 160 sq ft/acre. A clearcut is scheduled 20 years after the thin.

Regime Trigger Condition TO be eligible for this regime, a stand must be site quality 1, 2 or 3, and have no trees present.

Late-Seral Selection, Long (20-year) Cutting Cycle

Regime Codes 121-125

Starting Decades for the Regime

Regime Code	121	122	123	124	125
Starting Decade	1	***2***	***3***	***4***	***5***

Description

The goal of this regime is to create and maintain multistoried, uneven-aged, late-seral forest habitat. Selection harvesting will be used to enhance the growth of a few large trees while creating and maintaining special habitat elements including decadent trees, snags, downed logs, and other woody material.

At each selection harvest entry, the following targets are established:

Residual basal area is 240 sq ft/acre; however, no more than 40% of the basal area may be harvested in a single entry.

Of the desired residual basal area, the following percentages are to be left by diameter class:

DBH Class	Percent
4 to 8”	4.0 %
8 to 12”	7.0 %
12 to 16”	8.0 %
16 to 20”	9.0 %
20 to 24”	10.0 %
24 to 28”	12.0 %
28 to 32”	15.0 %
32 to 36”	15.0 %
36 to 40”	20.0 %
over 40”	0.0 %

Where all or a portion of these established targets exist in the stand, that target amount is retained in the selection harvest. If more than the target amount exists in a given size class, trees are harvested down to the target level. Additional stocking may be left in a size class to make up for a deficit in another class, so that the overall post-harvest stocking does not fall below minimum stand residual basal area levels. The stand may be entered every 20 years, if regime trigger conditions are met.

Regime Trigger Condition

Pre-harvest stand conditions must meet the following criteria:
Basal area/acre of at least 276 sq ft, and
Volume/acre of at least 20 MBF.

Late-Seral Selection, Long (20-year) Cutting Cycle, High Residual Basal Area

Regime Codes 131-135

Starting Decades for the Regime

Regime Code	131	132	133	134	135
Starting Decade	1	2	3	4	5

Description

The goal of this regime is to create and maintain multistoried, uneven-aged, late-seral forest habitat. Selection harvesting will be used to enhance the growth of a few large trees while creating and maintaining special habitat elements including decadent trees, snags, downed logs, and other woody material. This regime differs from the previous regime in that residual basal area levels and maximum tree diameters are increased, thus maintaining a larger, denser stand.

At each selection harvest entry, the following targets are established:

Residual basal area is 300 sq ft/acre; however, no more than 40% of the basal area may be harvested in a single entry.

Of the desired residual basal area, the following percentages are to be left by diameter class:

DBH Class	Percent
6 to 12”	8.0 %
12 to 18”	16.0 %
18 to 24”	12.0 %
24 to 30”	12.0 %
30 to 36”	15.0 %
36 to 42”	21.0 %
42 to 48”	16.0 %
over 48”	0.0 %

Where all or a portion of these established targets exist in the stand, that target amount is retained in the selection harvest. If more than the target amount exists in a given size class, trees are harvested down to the target level. Additional stocking may be left in a size class to make up for a deficit in another class, so that the overall post-harvest stocking does not fall below minimum stand residual basal area levels. The stand may be entered every 20 years, if regime trigger conditions are met.

Regime Trigger Condition

Pre-harvest stand conditions must meet the following criteria:
Basal area/acre of at least 345 sq ft, and
Volume/acre of at least 20 MBF.

Selection, Long (20-year) Cutting Cycle, Low Residual Basal Area

Regime Codes 301-305

Starting Decades for the Regime

Regime Code	301	302	303	304	305
Starting Decade	1	***2***	***3***	***4***	***5***

Description

The goal of this regime is to create and maintain multistoried, uneven-aged stands. Selection harvesting will be used to harvest trees throughout all diameter classes to achieve a diameter distribution with a l-inch diminution quotient of 1.25.

At each selection harvest entry, the following targets are established:

Residual basal area is 100 sq ft/acre; however, no more than 50% of the basal area may be harvested in a single entry.

Of the desired residual basal area, the following percentages are to be left by diameter class:

DBH Class	Percent
4 to ***8"***	***21.87%***
8 to 12"	***25.27%***
12 to 16"	***20.51%***
16 to 20"	13.98%
20 to 24"	***8.59%***
24 to 28"	***4.93%***
28 to 32"	***2.70%***
32 to 36"	1.42%
36 to 40"	***0.73%***
over 40"	***0 %***

Where all or a portion of these established targets exist in the stand, that target amount is retained in the selection harvest. If more than the target amount exists in a given size class, trees are harvested down to the target level. Additional stocking may be left in a size class to make up for a deficit in another class, so that the overall post-harvest stocking does not fall below minimum stand residual basal area levels. The stand may be entered every 10 years, if regime trigger conditions are met.

Regime Trigger Condition

Pre-harvest stand conditions must meet the following criteria:
Basal area/acre of at least 115 sq ft, and
Volume/acre of at least 8 MBF.

In addition, this regime may only be applied to site class 2 and 3 lands, as the 100 sq ft/acre minimum residual basal area would violate Forest Practice Rule standards for site 1 lands.

Selection, Long (20-year) Cutting Cycle, Medium Residual Basal Area

Regime Codes 321-325

Starting Decades for the Regime

Regime Code	321	322	323	324	325
Starting Decade	1	2	3	4	5

Description

The goal of this regime is to create and maintain multistoried, uneven-aged stands. Selection harvesting will be used to harvest trees throughout all diameter classes to achieve a diameter distribution with a l-inch diminution quotient of 1.25.

At each selection harvest entry, the following targets are established:

Residual basal area is 150 sq ft/acre; however, no more than 50% of the basal area may be harvested in a single entry.

Of the desired residual basal area, the following percentages are to be left by diameter class:

DBH Class	Percent
4 to 8”	21.87%
8 to 12”	25.27%
12 to 16”	20.51%
16 to 20”	13.98%
20 to 24”	8.59%
24 to 28”	4.93%
28 to 32”	2.70%
32 to 36”	1.42%
36 to 40”	0.73%
over 40”	0 %

Where all or a portion of these established targets exist in the stand, that target amount is retained in the selection harvest. If more than the target amount exists in a given size class, trees are harvested down to the target level. Additional stocking may be left in a size class to make up for a deficit in another class, so that the overall post-harvest stocking does not fall below minimum stand residual basal area levels. The stand may be entered every 10 years, if regime trigger conditions are met.

Regime Trigger Condition

Pre-harvest stand conditions must meet the following criteria:
Basal area/acre of at least 172 sq ft, and
Volume/acre of at least 8 MBF.

Selection, Normal (lo-year) Cutting Cycle, Medium Residual Basal Area

Regime Codes ***341-345***

Starting Decades for the Regime

Regime Code	341	342	343	344	345
Starting Decade	1	2	3	4	5

Description

The goal of this regime is to create and maintain multistoried, uneven-aged stands. Selection harvesting will be used to harvest trees throughout all diameter classes to achieve a diameter distribution with a 1 -inch diminution quotient of 1.25.

At each selection harvest entry, the following targets are established:

Residual basal area is 200 sq ft/acre; however, no more than 50% of the basal area may be harvested in a single entry.

Of the desired residual basal area, the following percentages are to be left by diameter class:

DBH Class	Percent
4 to 8”	21.87%
8 to 12”	25.27%
12 to 16”	20.5 1%
16 to 20”	13.98%
20 to 24”	8.59%
24 to 28”	4.93%
28 to 32”	2.70%
32 to 36”	1.42%
36 to 40”	0.73%
over 40”	0 %

Where all or a portion of these established targets exist in the stand, that target amount is retained in the selection harvest. If more than the target amount exists in a given size class, trees are harvested down to the target level. Additional stocking may be left in a size class to make up for a deficit in another class, so that the overall post-harvest stocking does not fall below minimum stand residual basal area levels. The stand may be entered every 10 years, if regime trigger conditions are met.

Regime Trigger Condition

Pre-harvest stand conditions must meet the following criteria:
Basal area/acre of at least 230 sq ft, and
Volume/acre of at least 12 MBF.

Selection, Normal (IO-year) Cutting Cycle, High Residual Basal Area

Regime Codes 361-365

Starting Decades for the Regime

Regime Code	361	362	363	364	365
Starting Decade	1	2	3	4	5

Description

The goal of this regime is to create and maintain multistoried, uneven-aged stands. Selection harvesting will be used to harvest trees throughout all diameter classes to achieve a diameter distribution with a l-inch diminution quotient of 1.25.

At each selection harvest entry, the following targets are established:

Residual basal area is 250 sq ft/acre; however, no more than 50% of the basal area may be harvested in a single entry.

Of the desired residual basal area, the following percentages are to be left by diameter class:

DBH Class	Percent
4 to 8”	21.87%
8 to 12”	25.27%
12 to 16”	20.51%
16 to 20”	13.98%
20 to 24”	8.59%
24 to 28”	4.93%
28 to 32”	2.70%
32 to 36”	1.42%
36 to 40”	0.73%
over 40”	0 %

Where all or a portion of these established targets exist in the stand, that target amount is retained in the selection harvest. If more than the target amount exists in a given size class, trees are harvested down to the target level. Additional stocking may be left in a size class to make up for a deficit in another class, so that the overall post-harvest stocking does not fall below minimum stand residual basal area levels. The stand may be entered every 10 years, if regime trigger conditions are met.

Regime Trigger Condition

Pre-harvest stand conditions must meet the following criteria:
Basal area/acre of at least 287 sq ft, and
Volume/acre of at least 12 MBF.

Clearcut, 60-year rotation, Extensive Management

Regime Codes	401-406

Starting Decades for the Regime							
	Regime Code	401	402	403	404	405	406
	Starting Decade	1	2	3	4	5	6

Description

Stands under this regime are managed on a 60-year rotation. After clearcut harvests, the stand is managed 'extensively'; i.e.- trees are planted but no other treatments (site preparation, brush control, pre-commercial thinning) are applied to the site.

Regime Trigger Condition

Pre-harvest stand volume/acre must be at least 8 MBF.

Clearcut, 60-year rotation, Intensive Management

Regime Codes	411-416

Starting Decades for the Regime							
	Regime Code	411	412	413	414	415	416
	Starting Decade	1	2	3	4	5	6

Description

Stands under this regime are managed on a 60-year rotation. After clearcut harvests, the stand is managed intensively; site preparation, planting, competing vegetation control, and pre-commercial thinning treatments are applied to the site.

Regime Trigger Condition

Pre-harvest stand volume/acre must be at least 8 MBF.

Clearcut, 60-year rotation, Commercial Thin at Age 50 to 200 sq ft./acre, Intensive Management

Regime Codes 421-426

Starting Decades for the Regime

Regime Code	421	422	423	424	425	426
Starting Decade	1	2	3	4	5	6

Description

Stands under this regime are managed on a 60-year rotation. The initial harvest will be a commercial thin if stand basal area is greater than 230 sq ft/acre and volume is between 10 and 25 MBF/acre. The residual basal area for thinned stands is 200 sq ft/acre or two-thirds of the pre-harvest basal area, whichever is greater. Stands that are thinned will be clearcut 10 years later.

The initial harvest will be a clearcut if stand basal area is greater than 200 sq ft/acre and volume is greater than 25 MBF/acre. A commercial thin is scheduled 50 years after the clearcut. After clearcut harvests, the stand is managed intensively; site preparation, planting, competing vegetation control, and pre-commercial thinning treatments are applied to the site.

Regime Trigger Condition

Pre-harvest stand conditions must meet the following criteria:
Basal area/acre of at least 200 sq ft, and
Volume/acre of at least 10 MBF.

Clearcut, 60-year rotation, Commercial Thin at Age 40 to 150 sq ft/acre, Intensive Management

Regime Codes 431-436

Starting Decades for the Regime

Regime Code	431	432	433	434	435	436
Starting Decade	1	2	3	4	5	6

Description

Stands under this regime are managed on a 60-year rotation. The initial harvest will be a commercial thin if stand basal area is greater than 172 sq ft/acre and volume is between 10 and 25 MBF/acre. The residual basal area for thinned stands is 150 sq ft/acre or two-thirds of the pre-harvest basal area, whichever is greater. Stands that are thinned will be clearcut 20 years later.

The initial harvest will be a clearcut if stand basal area is greater than 150 sq ft/acre and volume is greater than 25 MBF/acre. A commercial thin is scheduled 40 years after the clearcut. After clearcut harvests, the stand is managed intensively; site preparation, planting, competing vegetation control, and pre-commercial thinning treatments are applied to the site.

Regime Trigger Condition

Pre-harvest stand conditions must meet the following criteria:
Basal area/acre of at least 150 sq ft, and
Volume/acre of at least 10 MBF.

Clearcut, 60-year rotation, Commercial Thin at Age 40 to 100 sq ft/acre, Intensive Management

Regime Codes	441-446						
Starting Decades for the Regime	Regime Code	441	442	443	444	445	446
	Starting Decade	1	2	3	4	5	6

Description

Stands under this regime are managed on a 60-year rotation. The initial harvest will be a commercial thin if stand basal area is greater than 115 sq ft/acre and volume is between 10 and 25 MBF/acre. The residual basal area for thinned stands is 100 sq ft/acre or two-thirds of the pre-harvest basal area, whichever is greater. Stands that are thinned will be clearcut 20 years later.

The initial harvest will be a clearcut if stand basal area is greater than 100 sq ft/acre and volume is greater than 25 MBF/acre. A commercial thin is scheduled 40 years after the clearcut. After clearcut harvests, the stand is managed intensively; site preparation, planting, competing vegetation control, and pre-commercial thinning treatments are applied to the site.

Regime Trigger Condition

Pre-harvest stand conditions must meet the following criteria:
Basal area/acre of at least 100 sq ft, and
Volume/acre of at least 10 MBF.

This regime is not applied to site 1 lands, as the 100 sq ft./acre residual basal area level would violate Forest Practice Rule standards.

Clearcut, 80-year rotation, Extensive Management

Regime Codes	451-456						
Starting Decades for the Regime	Regime Code	451	452	453	454	455	456
	Starting Decade	1	2	3	4	5	6

Description

Stands under this regime are managed on a go-year rotation. After clearcut harvests, the stand is managed ‘extensively’; i.e.- trees are planted but no other treatments (site preparation, brush control, pre-commercial thinning) are applied to the site.

Regime Trigger Condition

Pre-harvest stand volume/acre must be at least 8 MBF

Clearcut, 80-year rotation, Intensive Management

Regime Codes	461-466

Starting Decades for the Regime	Regime Code	461	462	463	464	465	466
	Starting Decade	1	2	3	4	5	6

Description

Stands under this regime are managed on a 80-year rotation. After clearcut harvests, the stand is managed intensively; site preparation, planting, competing vegetation control, and pre-commercial thinning treatments are applied to the site.

Regime Trigger Condition

Pre-harvest stand volume/acre must be at least 8 MBF.

Clearcut, 80-year rotation, Commercial Thin at Age 60 to 150 sq ft/acre, Intensive Management

Regime Codes	471-476

Starting Decades for the Regime	Regime Code	471	472	473	474	475	476
	Starting Decade	1	2	3	4	5	6

Description

Stands under this regime are managed on a 80-year rotation. The initial harvest will be a commercial thin if stand basal area is greater than 172 sq ft/acre and volume is between 10 and 25 MBF/acre. The residual basal area for thinned stands is 150 sq ft/acre or two-thirds of the pre-harvest basal area, whichever is greater. Stands that are thinned will be clearcut 20 years later.

The initial harvest will be a clearcut if stand basal area is greater than 150 sq ft/acre and volume is greater than 25 MBF/acre. A commercial thin is scheduled 60 years after the clearcut. After clearcut harvests, the stand is managed intensively; site preparation, planting, competing vegetation control, and pre-commercial thinning treatments are applied to the site.

Regime Trigger Condition

Pre-harvest stand conditions must meet the following criteria:
Basal area/acre of at least 150 sq ft, and
Volume/acre of at least 10 MBF.

Clearcut, 80-year rotation, Commercial Thins at Age 40 to 100 sq ft/acre, Age 60 to 100 sq ft/acre, Intensive Management

Regime Codes 481-486

Starting Decades for the Regime

Regime Code	481	482	483	484	485	486
Starting Decade	1	2	3	4	5	6

Description

Stands under this regime are managed on a 80-year rotation. The initial harvest will be a commercial thin if stand basal area is greater than 115 sq ft/acre and volume is between 10 and 25 MBF/acre. The residual basal area for thinned stands is 100 sq ft/acre or two-thirds of the pre-harvest basal area, whichever is greater. Stands that are thinned will be clearcut 20 years later.

The initial harvest will be a clearcut if stand basal area is greater than 100 sq ft/acre and volume is greater than 25 MBF/acre. Commercial thins are scheduled 40 and 60 years after the clearcut; residual basal area for both thins is 100 sq ft/acre. After clearcut harvests, the stand is managed intensively; site preparation, planting, competing vegetation control, and pre-commercial thinning treatments are applied to the site.

Regime Trigger Condition

Pre-harvest stand conditions must meet the following criteria:
Basal area/acre of at least 100 sq ft, and
Volume/acre of at least 10 MBF.

This regime is not applied to site 1 lands, as the 100 sq ft/acre residual basal area level would violate Forest Practice Rule standards.

Clearcut, 80-year rotation, Commercial Thins at Age 50 to 200 sq ft/acre, Age 70 to 200 sq ft/acre, Intensive Management

Regime Codes 491-496

Starting Decades for the Regime

Regime Code	491	492	493	494	495	496
Starting Decade	1	2	3	4	5	6

Description

Stands under this regime are managed on a 80-year rotation. The initial harvest will be a commercial thin if stand basal area is greater than 230 sq ft/acre and volume is between 10 and 25 MBF/acre. The residual basal area for thinned stands is 200 sq ft/acre or two-thirds of the pre-harvest basal area, whichever is greater. Stands that are thinned will be clearcut 20 years later.

The initial harvest will be a clearcut if stand basal area is greater than 200 sq ft/acre and volume is greater than 25 MBF/acre. Commercial thins are scheduled 50 and 70 years after the clearcut; residual basal area for both thins is 200 sq ft/acre. After clearcut harvests, the stand is managed intensively; site preparation, planting, competing vegetation control, and pre-commercial thinning treatments are applied to the site.

Regime Trigger Condition

Pre-harvest stand conditions must meet the following criteria:
Basal area/acre of at least 200 sq ft, and
Volume/acre of at least 10 MBF.

Clearcut, 100-year rotation, Extensive Management

Regime Codes	501-511

Starting Decades for the Regime

Regime Code	501	502	503	504	505	506
Starting Decade	1	2	3	4	5	6

Description

Stands under this regime are managed on a l00-year rotation. After clearcut harvests, the stand is managed 'extensively'; i.e.- trees are planted but no other treatments (site preparation, brush control, pre-commercial thinning) are applied to the site

Regime Trigger Condition

Pre-harvest stand volume/acre must be at least 10 MBF

Clearcut, 100-year rotation, Intensive Management

Regime Codes	511-516

Starting Decades for the Regime

Regime Code	511	512	513	514	515	516
Starting Decade	1	2	3	4	5	6

Description

Stands under this regime are managed on a 100-year rotation. After clearcut harvests, the stand is managed intensively; site preparation, planting, competing vegetation control, and pre-commercial thinning treatments are applied to the site.

Regime Trigger Condition

Pre-harvest stand volume/acre must be at least 10 MBF

Clearcut, 100-year rotation, Commercial Thins at Age 60 to 150 sq ft/acre, Age 80 to 150 sq ft/acre

Regime Codes	521-526

Starting Decades for the Regime

Regime Code	521	522	523	524	525	526
Starting Decade	1	2	3	4	5	6

Description

Stands under this regime are managed on a 100-year rotation. The initial harvest will be a commercial thin if stand basal area is greater than 172 sq ft/acre and volume is between 10 and 25 MBF/acre. The residual basal area for thinned stands is 150 sq ft/acre or two-thirds of the pre-harvest basal area, whichever is greater. Stands that are thinned will be clearcut 20 years later.

The initial harvest will be a clearcut if stand basal area is greater than 150 sq ft/acre and volume is greater than 25 MBF/acre. Commercial thins are scheduled 60 and 80 years after the clearcut; residual basal area for both thins is 150 sq ft/acre. After clearcut harvests, the stand is managed intensively; site preparation, planting, competing vegetation control, and pre-commercial thinning treatments are applied to the site.

Regime Trigger Condition	Pre-harvest stand conditions must meet the following criteria: Basal area/acre of at least 150 sq ft, and Volume/acre of at least 10 MBF.

Clearcut, 100-year rotation, Commercial Thins at Ages 40, 60 & 80, all to 100 sq ft/acre, Intensive Management

Regime Codes 531-536

Starting Decades for the Regime

Regime Code	531	532	533	534	535	536
Starting Decade	1	2	3	4	5	6

Description

Stands under this regime are managed on a 100-year rotation. The initial harvest will be a commercial thin if stand basal area is greater than 115 sq ft/acre and volume is between 10 and 25 MBF/acre. The residual basal area for thinned stands is 100 sq ft/acre or two-thirds of the pre-harvest basal area, whichever is greater. Stands that are thinned will be clearcut 20 years later.

The initial harvest will be a clearcut if stand basal area is greater than 100 sq ft/acre and volume is greater than 25 MBF/acre. Commercial thins are scheduled 40, 60 and 80 years after the clearcut; residual basal area for each thinning entry is 100 sq ft/acre. After clearcut harvests, the stand is managed intensively; site preparation, planting, competing vegetation control, and pre-commercial thinning treatments are applied to the site.

Regime Trigger Condition

Pre-harvest stand conditions must meet the following criteria:
Basal area/acre of at least 100 sq ft, and
Volume/acre of at least 10 MBF.

This regime is not applied to site 1 lands, as the 100 sq ft/acre residual basal area level would violate Forest Practice Rule standards.

Clearcut, 50-year rotation, Intensive Management

Regime Codes 541-546

Starting Decades for the Regime

Regime Code	541	542	543	544	545	546
Starting Decade	1	2	3	4	5	6

Description

Stands under this regime are managed on a 50-year rotation. After clearcut harvests, the stand is managed intensively; site preparation, planting, competing vegetation control, and pre-commercial thinning treatments are applied to the site.

Regime Trigger Condition

Pre-harvest stand volume/acre must be at least 8 MBF

Clearcut, 50-year rotation, Extensive Management

Regime Codes 551-556

Starting Decades for the Regime

Regime Code	551	552	553	554	555	556
Starting Decade	1	2	3	4	5	6

Description

Stands under this regime are managed on a 50-year rotation. After clearcut harvests, the stand is managed 'extensively'; i.e.- trees are planted but no other treatments (site preparation, brush control, pre-commercial thinning) are applied to the site.

Regime Trigger Condition

Pre-harvest stand volume/acre must be at least 8 MBF

Seed Tree, 70-year rotation, Commercial Thin 50 years after Seed Step, to 125 sq ft/acre

Regime Codes 601 to 606

Starting Decades for the Regime

Regime Code	601	602	603	604	605	606
Starting Decade	1	2	3	4	5	6

Description

This regime initiates a seed tree seed step harvest if there is a basal area/acre of at least 150 sq ft and a volume/acre of at least 10 MBF. The seed step harvest leaves a basal area/acre of 50 sq ft; this residual basal area is in the largest trees present before the harvest that are less than 40" DBH.

A seed tree removal step harvest takes place twenty years after the seed step harvest. This harvest removes all trees greater than 18" DBH, and leaves up to 50 sq ft basal area/acre of trees less than 18" DBH.

A commercial thin takes place thirty years later. Residual basal area/acre is 125 sq ft. Twenty years following the commercial thin, a seed tree seed step harvest occurs again.

Regime Trigger Condition

Pre-harvest stand conditions must meet the following criteria:
Basal area/acre of at least 150 sq ft, and
Volume/acre must be at least 10 MBF.

Commercial Thin/Seed Tree, 70-year rotation, Commercial Thin 50 years after Seed Step, to 125 sq ft/acre

Regime Codes 611-616

Starting Decades for the Regime

Regime Code	611	612	613	614	615	616
Starting Decade	1	2	3	4	5	6

Description

This regime is similar to 601-606, except that it begins with the commercial thin harvest. The stand must have at least 150 sq ft and a volume/acre of at least 10 MBF; the harvest then cuts to a residual basal area/acre of 125 sq ft.

Twenty years after the commercial thin, a seed step harvest takes place. This harvest leaves a basal area/acre of 50 sq ft; this residual basal area is in the largest trees present before the harvest that are less than 40" DBH.

A seed tree removal step harvest takes place twenty years after the seed step harvest. This harvest removes all trees greater than 18" DBH, and leaves up to 50 sq ft basal area/acre of trees less than 18" DBH. Thirty years later, the stand is thinned again to 125 sq ft/acre.

Regime Trigger Condition

Pre-harvest stand conditions must meet the following criteria:
Basal area/acre of at least 150 sq ft, and
Volume/acre must be at least 10 MBF.

Shelterwood, 70-year rotation, Shelterwood Prep Step 50 years after Shelterwood Seed Step, to 125 sq ft/acre

Regime Codes 651-656

Startkg Decades for the Regime

Regime Code	651	652	653	654	655	656
Starting Decade	1	2	3	4	5	6

Description

This regime initiates a shelterwood seed step harvest if there is a basal area/acre of at least 150 sq ft and a volume/acre of at least 10 MBF. The seed step harvest leaves a basal area/acre of 75 sq ft; this residual basal area is in the largest trees present before the harvest that are less than 40" DBH.

A shelterwood removal step harvest takes place twenty years after the seed step harvest. This harvest removes all trees greater than 18" DBH, and leaves up to 75 sq ft basal area/acre of trees less than 18" DBH.

A shelterwood prep step harvest takes place thirty years later. Residual basal area/acre is 150 sq ft. Twenty years later, a shelterwood seed step harvest occurs again.

Regime Trigger Condition

Pre-harvest stand conditions must meet the following criteria:
Basal area/acre of at least 150 sq ft. and
Volume/acre must be at least 10 MBF.

Shelterwood PrepIShelterwood, 70-year rotation, Shelterwood Prep Step 50 years after Seed Step, to 125 sq ft/acre

Regime Codes	661-666						
Starting Decades for the Regime	Regime Code	661	662	663	664	665	666
	Starting Decade	1	2	3	4	5	6

Description

This regime is similar to 651-656, except that it begins with the shelterwood prep step harvest. The stand must have at least 180 sq ft and a volume/acre of at least 10 MBF; the harvest then cuts to a residual basal area/acre of 150 sq ft.

Twenty years after the prep step, a shelterwood seed step harvest takes place. This harvest leaves a basal area/acre of 75 sq ft; this residual basal area is in the largest trees present before the harvest that are less than 40" DBH.

A shelterwood removal step harvest takes place twenty years after the shelterwood seed step harvest. This harvest removes all trees greater than 18" DBH, and leaves up to 75 sq ft basal area/acre of trees less than 18" DBH. Thirty years later, a shelterwood prep step again thins the stand to 150 sq ft/acre.

Regime Trigger Condition

Pre-harvest stand conditions must meet the following criteria:
Basal area/acre of at least 180 sq ft, and
Volume/acre must be at least 10 MBF.

Active Timber Harvest Plans

Approximately 7% of PALCO's lands are within an active (filed and/or planned but not harvested) timber harvesting plan area. These areas were modeled via FREIGHTS code that approximates the harvest type that is intended to take place in the first decade. The decision model then has five sets of "post-decade 1" silvicultural treatments from which it may choose for each harvest type. These alternatives are listed below. A primarily consideration in the designof these alternatives was to give the scheduling model a range of choices with regard to the future decades in which harvests might take place on these lands-so that the model would not become 'locked in' to a rigid schedule of harvests on active THP lands.

First Decade Harvest	*Regime Code*	*Post-Decade I Silvicultural Activities*
Clearcut	701	50-year rotation, no thinnings
	702	60-year rotation, no thinnings
	703	60-year rotation, thin at age 40

	704	70-year rotation, thin at ages 30 and 50
	705	80-year rotation, thin at ages 40 and 60
Seed Tree Seed Step	7 11	Seed Tree Removal Step (STRS) in 10 years; then 60-year clearcut rotation, no thinnings
	712	STRS in 20 years; then 60-year clearcut rotation, thin at age 40
	713	STRS in 20 years; then 70-year seed tree rotation, no thinning
	714	STRS in 10 years; then 60-year seed tree rotation, thin at age 40
	715	STRS in 20 years; then 60-year seed tree rotation, thin at age 50
Seed Tree Removal Step	721	60-year clearcut rotation, no thinnings
	722	70-year clearcut rotation, thin at age 50
	723	70-year seed tree rotation, no thinnings
	724	80-year seed tree rotation, thin at ages 40 and 60
	725	80-year seed tree rotation, thin at age 60
Shelterwood Seed Step	731	Shelterwood Removal Step (SWRS) in 10 years; then 60-year clearcut rotation, no thinnings
	732	SWRS in 20 years; then 60-year clearcut rotation, thin at age 40
	733	SWRS in 20 years; then 70-year seed tree rotation, no thinning
	734	SWRS in 10 years; then 60-year seed tree rotation, thin at age 40
	735	SWRS in 20 years; then 60-year seed tree rotation, thin at age 50
Commercial Thin to 125 sq ft/acre	741	Clearcut in 20 years; then 50-year clearcut rotation, no thinnings
	742	Clearcut in 20 years; then 60-year clearcut rotation, thin at age 40
	743	Clearcut in 10 years; then 50-year clearcut rotation, thin at age 40
	744	Commercial thin in 20 years, clearcut in 40 years; then 70-year clearcut rotation, thins at age 30 and 50
	745	Commercial thin in 20 years, clearcut in 30 years; then 80-year clearcut rotation, thins at age 50 and 70
Commercial Thin to 150 sq ft/acre	751	Clearcut in 20 years; then 50-year clearcut rotation, no thinnings
	752	Clearcut in 20 years; then 60-year clearcut rotation, thin at age 40
	753	Clearcut in 10 years; then 50-year clearcut rotation, thin at age 40
	754	Commercial thin in 20 years, clearcut in 40 years; then 70-year clearcut rotation, thins at age 30 and 50
	755	Commercial thin in 20 years, clearcut in 30 years; then 80-year clearcut rotation, thins at age 50 and 70
Salvage (-1% of volume)	771	Clearcut in 20 years; then 60-year clearcut rotation, no thinnings

772 Commercial thin in 10 year, clearcut in 20 years; then 70-year clearcut rotation, thin at age 50

773 Seed tree seed step in 10 years, seed tree removal step in 20 years; then 60-year seed tree rotation, no thinnings

774 Seed tree seed step in 20 years, seed tree removal step in 30 years; then 60-year seed tree rotation, thin at age 30

775 Commercial thins in 10 and 30 years, clearcut in 50 years; then 80-year clearcut rotation, thins at ages 40 and 60

Regeneration Assumptions

Regeneration after harvest in these regimes is accomplished via arrays of small trees being introduced into the FREIGHTS modeling process immediately after harvest takes place. Three general types of regeneration are modeled:

- 1) Even-aged Intensive Management. Two hundred and fifty to three hundred trees/acre are "planted" following clearcut harvests. Ten percent of pre-harvest hardwood trees are assumed to sprout. In most of PALCO's lands, the planted trees are 50% redwood and 50% Douglas fir; however, in the BearLMattole watershed area the new trees are 100% Douglas fir to reflect the lack of naturally occurring redwood in this area. Intensive management assumes that site preparation, planting of improved seedlings, competing vegetation control and pre-commercial thinning treatments are applied as appropriate to promote rapid growth of young stands.

- 2) Even-age Extensive Management. One hundred and fifty trees/acre are planted following clearcut harvests and seed tree/shelterwood seed step harvests. Ninety percent of harvested hardwoods sprout. The 150 planted trees/acre is judged to appropriately model tree mortality and slower growth--relative to the 250-300 trees/acre planted in intensively managed regimes. As described above, the species mix is 50% redwood and 50% Douglas fir, except in the Bear/Mattole watershed area.

- 3) Selection Management. Eighty to one hundred and twenty small trees/acre (depending on stocking and density of the post-harvest stand) are introduced into each stand after selection harvests. Seventy-five percent of hardwoods are assumed to sprout. The species mix is 50% redwood and 50% Douglas fir, except in the Bear /Mattole watershed area.

SECTION 4 - RESOURCE SIMULATION

Introduction

This section describes the rationale, methodology, and accuracy, of the growth, harvest, and yield projection system used to model the outcomes of a wide range of silvicultural prescriptions on the lands of the Pacific Lumber Company. In order to meet the diverse goals and analysis needs of a SYP and a HCP, a comprehensive growth and yield simulation system was used to produce estimates of forest inputs and outputs associated with a very large number of silvicultural prescriptions (approximately 170). To support the analysis requirements and to evaluate the tradeoffs among various alternatives and resource conditions, the simulation system produced summaries of the following forest inputs and outputs over the 120-year planning horizon:

- Timber
- Wildlife Habitat Relationships
- Economics

FREIGHTS Growth and Yield Simulator

Forest product yields are generated using forest growth and yield models. Wildlife habitat relationships (WHR) are also derived for each silvicultural prescription on each strata type under consideration. Economic inputs and outputs are similarly derived. These models have been integrated into a single computer simulator that makes it feasible to examine large numbers of complex prescriptions. The growth and yield simulator, FREIGHTS^{TM} (Forest REsource Inventory, Growth, and Harvest Tracking System) developed by Dr. Bruce Krumland (Landring Corp, Berkeley, CA) was used to generate these yields.

FREIGHTS is an integrated software development environment consisting primarily of a specialty language, FREIGHTS Tree Growth Language (FI'GL), a compiler, librarian, linker, and runtime system housing the tree growth system. It is specifically designed to produce any number of projected management regimes for all strata types in a management unit. It can track any number of predefined timber statistics such as inventory, growth, harvests, mortality, etc. in terms of gross and net volumes, basal area, stand DBH, and trees per acre by any user-specified species grouping. It also has the ability to track by period any number of user-specified items by period such as acres partial cut, clear-cut, or rehabilitated; type and costs of regeneration measures, or WHR classifications.

FTGL-FREIGHTS Tree Growth Language

FTGL has been designed to contain language elements common to fourth-generation computer languages. These include various forms of program loops, conditional if/then/else forms of logic statements, case statement blocks, assignments, arrays, and a host of built-in commands to handle screen and file I/O, string parsing, numeric functions, etc. These features, coupled with the timber-specific features described below, provides a complete programmatic environment for developing management regimes for strata types.

Timber-related Features of FREIGHTS

Plot-based Growth

Growth is simulated by the FTGL growth command. FREIGHTS operates by growing each plot in a strata type inventory individually from midpoint to midpoint of successive growth periods. All plots are then aggregated to arrive at periodic stand statistics. While being much more time consuming than growing the "average plot," this process avoids all of the biases associated with plot aggregation and maintains a closer degree of conformity with actual forest conditions. All harvests and regeneration are assumed to take place at the midpoints of projection periods.

Plot-based Harvests

Harvests are accomplished by FTGL commands that allow highly resolute cutting prescriptions to be applied to each plot individually. The prescription is based on desired residual plot characteristics. This feature is designed to mimic as close as possible the actual on-the-ground operation of marking and felling crews. In instances where harvests fail to meet a desired criterion, additional commands are available to reinstate the pre-harvest state.

Plot-based Regeneration

Regeneration is accomplished by FTGL commands that allow stocking to be brought up to certain standards on each inventory/plot. As such, these plots are used as proxies for stocking standard plots and provides the mechanism necessary to insure that post-harvest stocking can be specified to be in compliance with stocking regulations, or any user-specified regeneration conditions.

Specific Timber Language Elements

FTGL contains over 80 built-in functions that allows virtually every stand statistic by any DBH range, and any combination of species groups or combination of species attributes to be examined by the programmer to make decisions about harvests, regeneration, or even the suitability of a proposed management regime for a specific strata type.

FREIGHTS Scripts, FTGL, and Forest Yield Files

A FREIGHTS script is essentially a computer file containing a series of silvicultural prescriptions coded in FTGL. TO run FREIGHTS, the user specifies several configuration files and a script file. Each strata type in the management unit is then subjected to any or all of the management regimes in the script under the control of the script programmer. Based on the logic included in the FTGL simulation script, yields are conditionally computed based on the characteristics of a given strata type. Strata types with special concerns, for instance, might have been limited to a subset of prescriptions appropriate to the conditions associated with those special concerns.

Another important design feature of FREIGHTS is its ability to evaluate stand stocking, growth, and harvest values at any time during the simulation process. This allows the simulator to mimic the way foresters work in the field, easily evaluating whether or not a particular regime is appropriate for a given stand, and modifying chosen regimes to meet varying stand conditions. For example, a FTGL script can adjust the harvest upwards or downwards until the volumes and basal areas harvested fall within an acceptable range. If harvest results are still unacceptable after adjustments the regime can be rejected as unsuitable or a different set of harvest rules can be applied.

Yields were generated using the specific site and stand conditions identified by the forest inventory plots associated with each specific strata type. A minimum of nine plots were individually simulated for each strata type.

Output from the run is a loaded into a relational database that contains a table for each forest input or output being tracked by FREIGHTS. Each row of the database contains the input or output for each planning period for a given strata type - prescription combination.

Custom Procedures for Simulating Non-timber Yields

FREIGHTS provides the capability to write custom procedure scripts to generate other yields such as WHR and economics that are related to predictions of forest structure and harvests over time. These yields are computed along with the timber yields, and are similarly written into the relational database.

Timber Growth and Yield

Choice of Modeling Methodology

The complexity of analysis and use of silvicultural systems relying on different species and size-specific forms of partial harvests dictates that a distance-independent tree-based growth model (Munro 1974) be used for stand growth, harvest, and yield projection. The model system used within FREIGHTS to project timber growth and yield for Pacific Lumber Company's lands was developed by Krumland (1982). This system forms the basis of the CRYPTOS computer model. The CRYPTOS model system was programmed into the FREIGHTS simulator by Krumland. A general consensus of CRYPTOS model users over the last twenty years indicates the model provides a reasonable prediction of stand development over a wide variety of stand conditions. Calibration factors were developed and applied to assure that the growth trajectories predicted by FREIGHTS matched either stand conditions found on PALCO property or published yield tables.

Computation of Long Term Sustained Yield

The computation of Long Term Sustained Yield (LTSY) is, of course, one of the essential elements of a SYP. The computation of LTSY is actually accomplished through the land allocation process, and is the sum of the average annual growth of the selected prescriptions. To enable the linear programming decision model to be constrained such that harvest was less than or equal to the LTSY level, the mean annual increment was computed for each even-aged prescription, and the mean annual periodic increment (for the last four planning periods) was computed for each uneven-aged prescription prior to formulation of the linear programming matrix. A more complete discussion of the land allocation process can be found below. A thorough analysis of the implications of computing LTSY using various methods is available upon request.

WHR Classification

Determining Wildlife Habitat Relationship Classification from Growth Simulation Model Outputs

The California Wildlife Habitat Relationships (WHR) system was developed to provide a tool to help resource professionals identify potential impacts of resource management decisions on wildlife. The basis of the WHR system is the ability to characterize vegetation by species, size, and density components and to use this characterization to help predict the presence of wildlife. For additional information on WHR, refer to *A Guide to Wildlife Habitats of California* (Mayer and Laudenslayer, 1988).

The California State Board of Forestry has required the use of the WHR system as a component of any sustained yield plan filed with the California Department of Forestry and Fire Protection (CDF). SYPs must include both a description of current and likely future vegetation in terms of WHR classification. This in turn requires a methodology to determine WHR classification from data available as inputs to and outputs from forest growth modeling software.

The conceptual framework for WHR is excellent but the actual implementation of WHR is difficult because of the lack of quantitative protocols for determining the WHR species, WHR size, and WHR density for a specific forested area. WHR classification is currently based upon a series of qualitative judgements often using decision rules that are poorly documented at best.

"The rules for placing a vegetation assemblage into a major habitat subdivision, and ultimately identifying the appropriate habitat, are problematic for any classification system. Nevertheless, arbitrary rules must be established to guide the classification, recognizing that human constructs do not always accommodate natural phenomena.... habitats are based on dominant existing vegetation. Dominance is based on:(1) amount (crown closure) or (2) a unique indicator of specific environmental conditions (i.e., Closed-cone pine Cypress)" (page IO).

The following discussion focuses on the problems and potential methods which could be used to classify tree-dominated WHR habitats using tree inventory information. The natural resource professionals writing and reviewing SYPs need a protocol for determining WHR types both in the field and in the office using objective, quantifiable measurements. These methods must be consistent with published WHR information.

WHR Size Classification

The WHR size determination is based upon the quadratic mean diameter of the trees present. Quadratic mean diameter (QMDBH) describes the diameter of a tree of average basal area.

The diameter of the smallest trees included in the basal area and number of tree calculations has a major effect on quadratic mean diameter.

Table 3 - Diameter and Basal Area Relationships

DBH (in.)	1.0	2.0	4.0	10.0	14.0	19.0	24.0	30.0
Basal Area (ft)	0.005	0.02	0.09	0.55	1.1	2.0	3.1	4.9

The California Department of Fish and Game (CDFG) has proposed a 5" minimum diameter for calculating QMDBH used to determine the WHR size class. While this limit is reasonable for stands with a few small trees and many larger trees, it makes it impossible to ever have a WHR size 1 classification and makes WHR size 2 almost impossible.

The method that was adopted for deciding which trees to use in the computation of QMDBH was to accumulate the proportion of basal area of successive size classes (beginning with the largest size first) until 75% of the strata type basal area was reached. Those tree size classes that contributed 75% of the strata type basal area were then used to compute the QMDBH.

Table 4 - Standards for Tree Size (Revised)

WHR Size	Description	Conifer Crown Diameter	Hardwood Crown Diameter	Quadratic Mean DBH
1	Seedling	n/a	n/a	< 1≤
2	Sapling	<12'	< 15'	1 to 5.99"
3	Pole	10 to 20'	10 to 30'	6 to 10.99"
4	Small Sawtimber	15' to 30'	18 to 45'	11 to 23.99"
5	Medium/Large Sawtimber	20' to 70'	30to 100'	>= 24"
6	Multi-Layered Habitat	n/a	n/a	n/a

WHR size class 4 is further subdivided into three QMDBH classes, 11.01"-15.99"(4.1), 16.00"-20.99" (4.2, and 21.00"-23.99" (4.3), WHR size class 5 was divided into two QMDBH classes, 24.00"-31.99" (5.1) and over 31.99" **(5.2).**

The determination of WHR size class is complicated by the need to decide if a stand is multi-soried, and whether or not it should be classified as a WHR size class 6, or where crown closure is too low, to classify the stand as a WHR size class 1. The procedures listed below are used to determine the WHR size class.

First calculate the WHR size class associated with the quadratic mean diameter, then calculate the total crown cover of all trees in that size class and larger size classes.

If total crown closure is greater than or equal to 10% and less than or equal to 60% then WHR size class equals the size class associated with the QMDBH.

If total crown closure is less than 10% then WHR SPECIES is not a tree class and WHR size class is NOT A TREE SIZE CLASS. Assume WHR size class is equal to 1.

If the sum of the canopy closure in WHR size classes 4 and 5 is > 60% and if percent canopy in size class 5 is less than 10% then WHR size class equals the size class associated with the QMDBH. Note that percent canopy refers to the percentage of total crown closure in a given size class.

If percent canopy in size class 5 is greater than or equal to 10% and less than or equal to 90% then a multi-storied stand may exist.

If percent canopy in size classes 3,4, and 5 is greater than 60% and the average height of size classes 3 and 4 trees are less than 50% of the average height of size class 5 trees then WHR size class equals 6, else WHR size class equals the size class associated with the QMDBH.

If percent canopy in size class 5 is greater than 90% then WHR size class equals the size class determined by QMDBH (probably a 5).

WHR Density Classification

The WHR size class is used to define the overstory. Only overstory trees were included in the calculation of canopy closure. For WHR size class 5 the WHR density call was based upon the sum of percent crown closure in WHR size class 5 trees. If the WHR size class is 4, then crown closure in size classes 4 and 5 were summed together to determine the crown closure. WHR percent canopy in size classes 3,4, and 5 were summed together to determine the canopy closure of WHR size class 3 stands,

Table 5 - Standards for Tree Canopy Closure

WHR	Closure Class	Overstory Canopy Closure
n/a	Not a Tree WHR Type	0 to 9.9910
S	Sparse Cover	10 to 24.99%
P	Open Cover	25 to 39.99%
M	Moderate Cover	40 to 59.99%
D	Dense Cover	60 to 100%

WHR Species Classification

Species classification is the most difficult and ambiguous area within the WHR system, Geographic location, elevation. aspect, and soils all help to determine the WHR species call along with the actual tree species present.

In *A Guide to Wildlife Habitats of California* (Mayer and Laudenslayer, 1988) Figure 1, entitled "Decision rules for wildlife habitat relationships (WHR) classification hierarchy" (page 11) appears to provide guidelines for determining specific tree habitat classification, but it contradicts the written descriptions of the habitats elsewhere in the document. An updated version of this figure entitled "Flow chart for mapping WHR conifer cover types" was developed by the Timberland Task Force.

Contradictions between the original flowchart and the text include: "Hardwood > 50% CC" to "Hardwood-Conifer > 25% but < 50% conifer" conflicts with the description of Montane Hardwood-Conifer MHC which states "To be considered MHC, at least one-third of the trees must be conifer and at least one-third must be broad-leaved..." (page 70). Another example, the flowchart specifies "Conifer > 50% CC" with the footnote "When sites are composed of two conifer species the habitat is determined by the species with the largest percentage canopy closure." This is incorrect for two reasons-most conifers do not have corresponding WHR types, and it contradicts the statement which allows for dominance to be based on "a unique indicator of specific environmental conditions (i.e., Closed-cone pine Cypress) (page lo)." The Pinyon-Juniper type PJN might be incorrectly identified as Juniper JUN if this "dominant cover" rule was applied.

There are many conifer species which could potentially dominate an area (e.g. Sitka spruce, western hemlock, Bishop pine, Monterey pine, grand fir, incense-cedar, sugar pine, mountain hemlock, Engelmann Spruce, western white pine, etc.) which have no corresponding WHR type. Of the fourteen conifer tree WHR types only eight are named after a single conifer species. One of those, redwood RDW, fits the exception category where dominance should be based upon "a unique indicator of specific environmental conditions." A coastal forest stand dominated by Sitka spruce and/or western hemlock is actually a WHR type Douglas-fir DFR and need not have any Douglas-fir present.

In the flowchart "Conifer > 50% CC" to "Mixed Conifer > 3 species" is totally incorrect; while both the Klamath KMC and Sierran Mixed Conifer SMC types often contain four or more species, a stand composed of white fir, incense-cedar, ponderosa pine, and California black oak is a SMC forest. There are many other conifer WHR types which could contain more than three species including RDW (redwood, Douglas-fir, western red cedar, grand fir, etc.),white fir WFR (white fir, sugar pine, incense-cedar, and red fir), DFR (Douglas-fir, redwood, Sitka spruce, western hemlock. etc.), EPN (ponderosa pine, Jeffrey pine, lodgepole pine, white fir, etc.), PPN (ponderosa pine, white fir, incense-cedar, Jeffrey pine, etc.), Jeffrey pine JPN (Jeffrey pine, ponderosa pine, Coulter pine, sugar pine, etc.).

The Timberland Task Force revised figure "Flow chart for mapping WHR conifer cover types" is more consistent with the published WHR type descriptions but still contains errors: "Conifer > 33% CC and Hardwood > 33% of Tree CC" is consistent with the description of Montane Hardwood-Conifer MHC but could also lead one to identify Sierran Mixed Conifer SMC as Montane Hardwood-Conifer if the California black oak tree CC exceeded 33%.

Before the WHR species can be determined, three categories of WHR species types must be recognized since the rules used to determine species vary with the type of habitat being identified.

WHR types based upon “a unique indicator of specific environmental conditions”
Blue Oak-Digger Pine BOP
Closed-cone Pine-Cypress CPC
JST Joshua Tree
Palm Oasis POS
Pinyon-Juniper PJN
Redwood RDW

- WHR types based upon complex decision rules including geographic location
Coastal Oak Woodland COW
Douglas-fir DFR
Eastside Pine EPN
Klamath Mixed Conifer KMC
Montane Hardwood MHW
Montane Hardwood-Conifer MHC
Montane Riparian MRI
Sierran Mixed Conifer SMC
Subalpine Conifer SCN
Valley Foothill Riparian VRI
Valley Oak Woodland VOW
- WHR types based upon the predominant conifer or hardwood present
Aspen ASP
Blue Oak BOP (if not Blue Oak-Digger Pine BOP)
Eucalyptus EUC
Jeffrey Pine JPN
Juniper JUN (if not Pinyon-Juniper PJN)
Lodgepole Pine LPN
Ponderosa Pine PPN
Red Fir RFR
White Fir WFR

Determining WHR Vegetation Type

Overstory vegetation was used determine the WHR vegetation type. For tree WHR size classes 1, 2, 3,4, and 5 the WHR species call was based upon the percent crown closure (by species) in all size classes greater than or equal to the WHR size class. For example, if the WHR size class is 4, then crown closure in size classes 4 and 5 was summed together to determine the species composition of the overstory. For WHR size class 6 the WHR species call was based upon the species composition of size classes 3, 4, and 5 combined. Geographic location is very important, but is not stored in the tree list. The following steps were used to determine the WHR vegetation type:

- Determine whether “a unique indicator of specific environmental conditions” is present.
- Check for the presence of Bishop pine, Monterey pine, or cypress. If the total cover in these three species is greater than 50%, then WHR veg type is CPC (Closed-cone Pine-Cypress).
- If redwood cover is greater than 40% of the total tree overstory cover or conifer cover is greater than 50% and redwood cover is greater than 50% of the total conifer cover then the WHR veg type is RDW (Redwood).
- If there is not “a unique indicator of specific environmental conditions” then determine if other special geographic conditions apply.
- If hardwood cover is greater than 33% and less than 67% then WHR veg type equals MHC (Montane Hardwood-Conifer).
- If hardwood cover is greater than 50% then WHR veg type equals MHW (Montane Hardwood). This was used but needs to be expanded to check for other hardwood WHR veg types.
- If conifer cover is greater than 50% and redwood cover is less than 40% the WHR veg type is DFR (Douglas-fir).
- Classify remaining areas based upon the predominant conifer or hardwood present.
- If tree cover is less than 10% then WHR veg type is CS (Coastal Scrub).

Deriving Northern Spotted Owl Habitat and Forest Seral Stages

Table 6 shows how northern spotted owl habitat type and quality and forest seral stages were derived from each WHR type:

Table 6 – WHR Types and Associated Habitat Characteristics

WHR Type	NSO Habitat	Nesting Quality	Seral Stage
CSC1_M	Non-Habitat	Non-Habitat	Forest Open
CSC3_M	Non-Habitat	Non-Habitat	Hardwood
DFR1_D	Non-Habitat	Non-Habitat	Forest Open
DFR1_M	Non-Habitat	Non-Habitat	Forest Open
DFR1_P	Non-Habitat	Non-Habitat	Forest Open
DFR1_S	Non-Habitat	Non-Habitat	Forest Open
DFR2_D	Foraging Habitat	Foraging Habitat	Young Forest
DFR2_M	Foraging Habitat	Foraging Habitat	Young Forest
DFR2_P	Non-Habitat	Non-Habitat	Young Forest
DFR2_S	Non-Habitat	Non-Habitat	Young Forest
DFR3_D	Roosting Habitat	Roosting Habitat	Young Forest
DFR3_M	Roosting Habitat	Roosting Habitat	Young Forest
DFR3_P	Roosting Habitat	Roosting Habitat	Young Forest
DFR3_S	Roostina Habitat	Roostine Habitat	Youne Forest
DFR4AD		Low Quality Nesting Habitat	Mid-successional
DFR4AM		Low Quality Nesting Habitat	Mid-successional
DFR4AP		Low Quality Nesting Habitat	Mid-successional
DFR4AS		Low Quality Nesting Habitat	Mid-successional
DFR4BD		Low Quality Nesting Habitat	Mid-successional
DFR4BM		Low Quality Nesting Habitat	Mid-successional
DFR4BP		Low Quality Nesting Habitat	Mid-successional
DFR4BS		Low Quality Nesting Habitat	Mid-successional
DFR4CD		Low Quality Nesting Habitat	Mid-successional
DFR4CM		Low Quality Nesting Habitat	Mid-successional
DFR4CP		Low Quality Nesting Habitat	Mid-successional
DFR4CS		Low Quality Nesting Habitat	Mid-successional
DFR5_D		High Quality Nesting Habitat	Late Seral
DFR5_M		High Quality Nesting Habitat	Late Seral
DFR5_P		Low Quality Nesting Habitat	Mid-successional
DFR5_S		Low Quality Nesting Habitat	Mid-successional
DFR5AD		High Quality Nesting Habitat	Late Seral
DFR5AM		High Quality Nesting Habitat	Late Seral
DFR5AP		Low Quality Nesting Habitat	Mid-successional
DFR5AS		Low Quality Nesting Habitat	Mid-successional
DFRSBP		Low Quality Nesting Habitat	Mid-successional
DFR5BS		Low Quality Nesting Habitat	Mid-successional
DFR6_D		High Quality Nesting Habitat	Late Seral
MCP	Non-Habitat	Non-Habitat	Forest Open
MCP1_D	Non-Habitat	Non-Habitat	Forest Open
MCP1_M	Non-Habitat	Non-Habitat	Forest Open
MCP1_P	Non-Habitat	Non-Habitat	Forest Open
MCP1_S	Non-Habitat	Non-Habitat	Forest Open
MHC1_D	Non-Habitat	Non-Habitat	Forest Open
MHC1 M	Non-Habitat	Non-Habitat	Forest Open
MHC1_P	Non-Habitat	Non-Habitat	Forest Open
MHC1_S	Non-Habitat	Non-Habitat	Forest Open
MHC2_D	Roosting Habitat	Roosting Habitat	Young Forest
MHC2_M	Non-Habitat	Non-Habitat	Young Forest

MHC2_P	Non-Habitat	Non-Habitat	Young Forest
MHC2_S	Non-Habitat	Non-Habitat	Young Forest
MHC3_D	Roosting Habitat	Roosting Habitat	Young Forest
MHC3_M	Roosting Habitat	Roosting Habitat	Young Forest
MHC3_P	Non-Habitat	Non-Habitat	Young Forest
MHC3_S	Non-Habitat	Non-Habitat	Young Forest
MHC4AD		Low Quality Nesting Habitat	Mid-successional
MHC4AM		Low Quality Nesting Habitat	Mid-successional
MHC4AP	Roosting Habitat	Roosting Habitat	Mid-successional
MHC4AS	Non-Habitat	Non-Habitat	Mid-successional
MHC4BD		Low Quality Nesting Habitat	Mid-successional
MHC4BM		Low Quality Nesting Habitat	Mid-successional
MHC4BP	Roosting Habitat	Roosting Habitat	Mid-successional
MHC4BS	Non-Habitat	Non-Habitat	Mid-successional
MHC4CD		Low Quality Nesting Habitat	Mid-successional
MHC4CM		Low Quality Nesting Habitat	Mid-successional
MHC4CP	Roosting Habitat	Roosting Habitat	Mid-successional
MHC5_D		High Quality Nesting Habitat	Late Seral
MHC5_M		Mid-Quality Nesting Habitat	Late Seral
MHC5_P		Low Quality Nesting Habitat	Mid-successional
MHC5_S		Low Quality Nesting Habitat	Mid-successional
MHC5AD		High Quality Nesting Habitat	Late Seral
MHC5AM		Mid-Quality Nesting Habitat	Late Seral
MHC5AP		Low Quality Nesting Habitat	Mid-successional
MHC5AS		Low Quality Nesting Habitat	Mid-successional
MHC5BD		High Quality Nesting Habitat	Late Seral
MHC5BM		Mid-Quality Nesting Habitat	Late Seral
MHC6_D		High Quality Nesting Habitat	Late Seral
MHW1_D	Non-Habitat	Non-Habitat	Hardwood
MHW1_M	Non-Habitat	Non-Habitat	Hardwood
MHW1_P	Non-Habitat	Non-Habitat	Hardwood
MHW1_S	Non-Habitat	Non-Habitat	Hardwood
MHW2_D	Roosting Habitat	Roosting Habitat	Hardwood
MHW2_M	Roosting Habitat	Roosting Habitat	Hardwood
MHW2_P	Non-Habitat	Non-Habitat	Hardwood
MHW2_S	Non-Habitat	Non-Habitat	Hardwood
MHW3_D	Roosting Habitat	Roosting Habitat	Hardwood
MHW3_M	Roosting Habitat	Roosting Habitat	Hardwood
MHW3_P	Non-Habitat	Non-Habitat	Hardwood
MHW3_S	Non-Habitat	Non-Habitat	Hardwood
MHW4AD		Low Quality Nesting Habitat	Hardwood
MHW4AM		Low Quality Nesting Habitat	Hardwood
MHW4AP	Roosting Habitat	Roosting Habitat	Hardwood
MHW4AS	Roosting Habitat	Roosting Habitat	Hardwood
MHW4BD		Low Quality Nesting Habitat	Hardwood
MHW4BM		Low Quality Nesting Habitat	Hardwood
MHW4BP	Roosting Habitat	Roosting Habitat	Hardwood
MHW4BS	Roosting Habitat	Roosting Habitat	Hardwood
MHW4CD		Low Quality Nesting Habitat	Hardwood
MHW5_D		High Quality Nesting Habitat	Hardwood
MHW5 M		Mid-Quality Nesting Habitat	Hardwood

MHW5_P		Low Quality Nesting Habitat	Hardwood
MHW5_S		Low Quality Nesting Habitat	Hardwood
MHW5AD		High Quality Nesting Habitat	Hardwood
MHW6_D		High Quality Nesting Habitat	Hardwood
PGS2_D	Non-Habitat	Non-Habitat	Grass
RDW 1-D	Non-Habitat	Non-Habitat	Forest Open
RDW1_M	Non-Habitat	Non-Habitat	Forest Open
RDW1_P	Non-Habitat	Non-Habitat	Forest Open
RDW1_S	Non-Habitat	Non-Habitat	Forest Open
RDW2_D	Foraging Habitat	Foraging Habitat	Young Forest
RDW2_M	Foraging Habitat	Foraging Habitat	Young Forest
RDW2_P	Foraging Habitat	Foraging Habitat	Young Forest
RDW2_S	Foraging Habitat	Foraging Habitat	Young Forest
RDW3_D		Low Quality Nesting Habitat	Young Forest
RDW3_M		Low Quality Nesting Habitat	Young Forest
RDW3_P	Foraging Habitat	Foraging Habitat	Young Forest
RDW3_S	Foraging Habitat	Foraging Habitat	Young Forest
RDW4AD		High Quality Nesting Habitat	Mid-successional
RDW4AM		Mid-Oualitv Nesting Habitat	Mid-successional
RDW4AP		Low Oualitv Nesting Habitat	Mid-successional
RDW4AS		Low Quality Nesting Habitat	Mid-successional
RDW4BD		High Quality Nesting Habitat	Mid-successional
RDW4BM		Mid-Quality Nesting Habitat	Mid-successional
RDW4BP		Low Quality Nesting Habitat	Mid-successional
RDW4BS		Low Quality Nesting Habitat	Mid-successional
RDW4CD		High Quality Nesting Habitat	Mid-successional
RDW4CM		Mid-Quality Nesting Habitat	Mid-successional
RDW4CP		Low Quality Nesting Habitat	Mid-successional
RDW4CS		Low Quality Nesting Habitat	Mid-successional
RDW5_D		High Quality Nesting Habitat	Late Seral
RDW5_M		High Quality Nesting Habitat	Late Seral
RDW5_P		Low Quality Nesting Habitat	Mid-successional
RDW5_S		Low Quality Nesting Habitat	Mid-successional
RDW5AD		High Quality Nesting Habitat	Late Seral
RDW5AM		High Quality Nesting Habitat	Late Seral
RDW5AP		Low Quality Nesting Habitat	Mid-successional
RDW5AS		Low Quality Nesting Habitat	Mid-successional
RDW5BD		High Quality Nesting Habitat	Late Seral
RDW5BM		High Quality Nesting Habitat	Late Seral
RDW5BP		Low Quality Nesting Habitat	Mid-successional
RDW5BS		Low Quality Nesting Habitat	Mid-successional
RDW6_D		High Quality Nesting Habitat	Late Seral
DFR5BD		High Quality Nesting Habitat	Late Seral
DFR5BM		High Quality Nesting Habitat	Late Seral
MHC4CS	Non-Habitat	Non-Habitat	Mid-successional
MHW4CP	Roosting Habitat	Roosting Habitat	Hardwood
MHW5AM		High Quality Nesting Habitat	Late Seral
MHW5AP		High Quality Nesting Habitat	Late Seral
MHW5AS		High Quality Nesting Habitat	Late Seral
MHC5BS		Low Quality Nesting Habitat	Mid-successional
MHW4CM	Roosting Habitat	Roosting Habitat	Hardwood

Economic Parameters

Discounted Net Revenue Calculation

As trees are harvested within the FREIGHTS simulator, revenues and costs are calculated on a per acre basis and written to the FREIGHTS output tables. Economic values such as gross revenue, silviculture cost, and yarding cost figures used in the FREIGHTS model are listed below.

Present net worth (PNW), or discounted cash flow from each silvicultural prescription is calculated at the the linear programming matrix is created. Gross revenue, silviculture costs, and yarding costs are extracted from FREIGHTS output tables, and a harvest value is computed. A discounting factor is applied as a coefficient to each harvest value.

For each landtype/prescription combination considered by the linear program the non-discounted net revenue per acre per period is calculated as:

- HRVAL = REVNU - SILVCOST - (CCOST or TCOST or HCOST)

When the linear program uses maximization of PNW as an objective function, it would appear in its equation form as:

- Maximize (.74726 * HRVAL01) + (.41727 * HRVAL02) + (.23300 * HRVAL03) + (.13011 * HRVAL04) + (.07265 * HRVAL05) + (.04057 * HRVAL06) + (.02265 * HRVAL07) + (.01265 * HRVAL08) + (.00706 * HRVAL09) + (.00394 * HRVAL10) + (.00220 * HRVAL11) + (.00123 * HRVAL12)

Where the discount rate is 6%.

Gross Revenue

Gross revenue is a function of tree species and tree DBH. Values used are as follows:

Young-growth Redwood

DBH	$/MBF
8.00-15"	600
15.01-19"	614
19.01-21"	618
21.01-25"	629
25.01-29"	644
29.01-31"	653
31.01-35"	660
35.01-37"	669
37.01-41"	676
41.01-47"	684
47.01-53"	697
53.01-57"	703
57.01-61"	709
61.01-63"	714
63.01-65"	720
65.01-71"	724
71.01-75"	731
75.01-81"	735
81.01-83"	739
83.01-93"	741
93.01-95"	744
95.01-105"	746
105.01-121"	750
121.01-143"	753
143.01+"	755

Young-growth Douglas-fir

DBH	$/MBF
8.00-13"	500
13.01-15"	513
15.01-17"	519
17.01-21"	528
21.01-23"	535
23.01-25"	542
25.01-27"	552
27.01-31"	559
31.01-33"	568
33.01-35"	574
35.01-37"	580
37.01-41"	584
41.01-43"	590
43.01-47"	595
47.01-49"	599
49.01-53"	603
53.01-55"	609
55.01-61"	615
61.01-63"	619
63.01-69"	622
69.01-83"	627
83.01-+"	632

Old-growth Redwood

DBH	$/MBF
8.00-15"	600
15.01-19"	634
19.01-21"	646
21.01-25"	672
25.01-29"	710
29.01-31"	731
31.01-35"	749
35.01-37"	773
37.01-41"	791
41.01-47"	828
47.01-51"	870
51.01-53"	883
53.01-57"	908
57.01-59"	939
59.01-61"	946
61.01-63"	963
63.01-65"	1006
65.01-69"	1030
69.01-71"	1041
71.01-75"	1072
75.01-81"	1096
81.01-83"	1122
83.01-93"	1135
93.01-95"	1156
95.01-105"	1167
105.01-111"	1182
111.01-121"	1190
121.01-129"	1201
129.01-143"	1208
143.01-153"	1217
153.01+"	1221

Old-growth Douglas-fir and Other Whitewroods

DBH	$/MBF
8.00-17"	550
17.01-21"	605
21.01-23"	636
23.01-25"	648
25.01-27"	677
27.01-29"	693
29.01-31"	702
31.01-33"	719
33.01-35"	734
35.01-37"	746
37.01-41"	778
41.01-43"	791
43.01-47"	814
47.01-49"	845
49.01-53"	856
53.01-55"	871
55.01-59"	901
59.01-61"	915
61.01-63"	926
63.01-67"	942
67.01-69"	954
69.01-73"	967
73.01-75"	973
75.01-79"	979
79.01-83"	988
83.01-89"	995
89.01-93"	1001
93.01-97"	1009
97.01-+"	1012

Young-growth Whitewoods (Grand Fir, Hemlock, Red Cedar, Sitka Spruce)

DBH	$/MBF
8.00-17"	300
17.01-21"	309
21.01-23"	314
23.01-25"	325
25.01-27"	330
27.01-31"	339
31.01-33"	345
33.01-35"	355
35.01-37"	362
37.01-39"	382
39.01-41"	387
41.01-43"	405
43.01-47"	420
47.01-53"	445
53.01-61"	468
61.01-63"	473
63.01-69"	487
69.01-75"	490
75.01-79"	495
79.01-81"	499
81.01-97"	502
97.01-+"	506

Hardwoods: $233/MBF for all tree sizes and species

Silvicultural Costs

The silvicultural costs in Table 7 are applied for the decade in which harvest took place:

Table 7 – Silvicultural Costs

Treatment/Harvest	Cost
Intensive Clearcut	$593/acre
Restocking	$593/acre
Extensive Clearcut	$150/acre (planting in year 0 only)
Selection	$150/acre
Seed Tree Seed Step	$150/acre
Shelterwood Seed Step	$150/acre

The clear-cut and restocking costs are based on data displayed in Table 8:

Table 8 – Even-age Cultural Costs

Cultural Treatment	Year	Cost/acre
Site Preparation	0	$120
Planting	0	$150
Pre-emergent spray	0	$120
Release spray	2	$140
Precommercial thin	10	$140
Discounted total		$593

Yarding Costs

For conifers, yarding costs are a function of yarding method and volume per acre harvested, as displayed in Table 9:

Table 9 – Yarding Costs

	Volume Harvested in MBF/acre			
	30+	20-30	10-20	0-10
Tractor yarding	$120/MBF	$140/MBF	$160/MBF	$180/MBF
Cable yarding	$140/MBF	$160/MBF	$180/MBF	$200/MBF
Helicopter yarding	$250/MBF	$270/MBF	$290/MBF	$310/MBF

For hardwoods. regardless of yarding method and volume harvested: $200/MBF. Yarding for all selection prescriptions is 30% higher.

Note: Gross revenue and yarding costs are expressed above on a "per MBF' basis. However, they are written to FREIGHTS output tables on a "per acre" basis; this is accomplished by multiplying the MBF/acre harvested by the revenue or cost/acre figures listed above.

Accuracy of Growth Estimates

Accuracy, in a conventional statistical sense, is an estimate of how close a predictor is to actual conditions. This estimate combines measures of both bias and variability. For growth estimates used in an SYP, accuracy measures involve assessments of predictions of growth by stand and treatment type over all time periods in the plan as well as aggregate estimates for the ownership. FREIGHTS was compared to CRYPTOS, CACTOS, and FVS (commonly used forest growth and yield simulators for California forests) to establish its relative ability to predict growth. A FREIGHTS Validation Study Report completed by CAMFER at UC Berkeley is available upon request.

The accuracy of the growth estimates used in the SYP can be summarized in the following way:

Least squares estimators were used to derive parameters for all of the equations use in the growth model system. Least squares estimates are theoretically known to be unbiased and have minimum variance.

The structure of the model system in terms of form, relationships, and propagation of error terms was clearly identified and estimation procedures were used that guaranteed a high degree of conformance between methods of estimation and the way the model system was used in forecasting operations.

The CRYPTOS model system was calibrated for tree basal area and height growth to all growth data available to the redwood research cooperative in 1982 (Krumland 1982). The growth data consisted of all trees on over 1500 growth plot measurements collected between 1930 and 1980. This guarantees that overall, the main components of the model system are centered at their long-term historical levels.

Krumland (1982) has made several empirical comparisons with the CRYPTOS system to growth plot time series ranging between fifteen and forty years in length. While it was indicated that there was considerable variability between growth plots, the general level of the predictions as well as the yield trajectories over time were in general agreement with the empirical basis.

While not being a classical Turing test, there seems to be general consensus of CRYPTOS model users over the last 20 years that the model provides a reasonable prediction of stand development over a wide variety of stand conditions. Simulations of even-aged stands with both models also indicated that both had the classical yield forms and were within the yield levels experienced within the state.

Last, virtually all growth functions in both model systems are strongly tied to site index curves. Site curves are considered to be the most stable part of the model systems as they have been developed from long-term time series of trees from known stand components.

In summary, the models used in the PALCO SYP were made to be as accurate as possible given the methods and data available at the time of construction. More resolute measures of accuracy must be deferred until sufficient long-term timber growth plot series are available for comparative purposes.

- SECTION 5 - LAND ALLOCATION

Decision Analysis

The various yields produced throughout the 120-year planning horizon by each of the management prescriptions, together with the available acreage of each land type, are stored in a Microsoft Access database. Similarly, management objectives and operational and environmental constraints are included in the matrix. The linear programming solution allocates land uses over time, that is; it optimizes the number of acres allocated to each management prescription on each land type relative to the specified management and environmental objectives and constraints. It is largely through this process that a balance is struck between maximum sustained timber production and other resource values.

The SYP problem contains three levels of data and policy constraints:

- Land Type
- WAA
- Management Unit

The most basic linear programming (LP) information is at the land type level. The LP input matrix must contain all relevant land type yield information and must contain area conservation constraints that force the LP to assign one or more management prescriptions to the exact number of acres found in each land type. Every acre must be allocated and no acre can be allocated more than once.

The only policies associated with land types are those that deal with the allowable range of prescriptions. For example, PALCO policy limits the range of silviculture in Class I stream zones to a late seral selection prescription or a no harvest prescription. These policies were implemented using the special concern codes in the yield generation phase of the SYP.

If further land type restrictions are required they could be implemented during matrix generation by giving the matrix generator a list of “approved” regimes so that no data is written to the matrix for regimes that are not under consideration.

WAA Constraints

WAA-level data and constraints deal with groups of land types which are all found in the same WAA. The incorporation of WAA-level constraints is an innovative and important feature of PALCO’s planning model since it allows for true landscape planning. For example, WWAA-level constraints were used to set habitat targets to assure that various types of desired habitat were well-distributed across the landscape.

There is no direct yield generation from FREIGHTS at the WAA level. WAA yields are calculated using accounting variables which sum the value of individual land type variables into an accounting row. These accounting rows are used to compute and track the total acreage of the WAA, and various other pertinent outputs.

Harvest Type Constraints

Harvest type accounting rows track different types of harvests such as clear-cut, commercial thin, rehabilitation, seed tree seed step, seed tree removal step, shelterwood seed step, shelterwood removal step, sanitation salvage, and alternative prescriptions. These were also combined into the Disturbance Index accounting variable, allowing WAA or management unit specific constraints.

Habitat Type Constraints

Various seral stage and habitat quality accounting rows were used for tracking and constraining desired levels through time.

Management Unit Constraints

Management unit constraints are used to define the objective function and to set broad targets and restrictions. They are created using accounting rows which sum across the entire problem,

Linear Programming Solution

Once the MPS input files were created the linear programming problem was input into C-WHIZ (Version 2.01, March 8, 1995, Ketron Management Science, 2200 Wilson Blvd. Suite 220, Arlington, VA 22201) and solved. C-WHIZ creates an ASCII output file, which contains the linear programming problem solution.

Mapping and Report Generations

The sysprint file created by C-WHIZ contains a tremendous amount of data about the linear programming solution but is difficult to interpret without further processing. A policy alternative model (PAM) database, maps, and reports (graphical and tabular) are produced to assist the assessment teams in interpreting the results of the land use allocation. These maps and reports provide a consistent basis for evaluation by interdisciplinary teams.

Creation of Simple Linear Program Solution Files

The first level of report generation takes the sysprint file and processes it to create the following comma-separated ASCII files: *1andtype.rx lp_ans2.out,* and *lp_ans3.out,* a sorted version of *lp_ans2.out.*

The *landtype.rx* file contains the eight character hexadecimal land type/regime code used as a column name in the linear programming matrix, and the number of acres allocated by the linear program to that land type and regime.

The *lp_ans2.out* and *lp_ans3.out* files contain the same information but it is sorted differently. These files contain the non-zero accounting and constraint row values, and provide a quick overview of the solution but are limited to information found in the *sysprint* file. These files can easily be summarized in a spreadsheet program to quickly provide a summary of the alternate management scenario. The *lp_ans3.out* file also loaded into the PAM database to serve as the basis or more detailed reporting.

Detailed Yield Information

Detailed yield information associated with the alternative management scenario can be created by linking the PAM database, which contains information on the landtype--prescription acreage allocation from the linear programming solution, to the RCM database. Using the relational database capabilities of the PAM and RCM databases, virtually all information previously generated about forest inputs and outputs can be summarized and reported.

Linking the LP solution Back to the GIS

The land type table that was created through GIS processing (as described above in land type analysis), and is added to the PAM database. It contains the land type code used in the GIS land type coverage, the FREIGHTS regime code, an eight character hexadecimal land type--prescription code used as a column name in the linear programming matrix, and the number of acres allocated by the linear program to that landtype and prescription. This table is now used to link a linear programming solution back to the GIS land type coverage.

The algorithm used to link the LP solution back the GIS is done in two parts:

- A simple relational join of land types allocated a single prescription
- An acreage matching algorithm for land types allocated more than one prescription

Most of the land types (typically over 95%) are allocated a single prescription. For each multiple prescription landtype, the polygons associated with that landtype are selected and sorted by their size. Based upon the LP solution acres, a single polygon that best meets the acreage requirement is sought. A fuzzy tolerance set by the user (generally 1 - 2 acres) is used to define the upper and lower tolerances of acceptability. If a single polygon can not be located the algorithm then attempts to select a subset of polygons whose acreage sums to the LP solution acres. Starting with the largest polygon that is less than or equal to the LP solution, the algorithm then continues to add polygons to the list as long as the they do not exceed the solution acres.

Once a solution is found within the fuzzy tolerance, the solution is then assigned to those polygons. If the list is exhausted and an acceptable solution was not found, the algorithm then discards the largest polygon and attempts to resolve the allocation with a new set of polygons. Once a satisfactory allocation has been achieved. the algorithm then proceeds to the next LP allocation for that landtype. This process continues for each multiple prescription for a land type. When the last allocation is being processed, all remaining polygons unassigned are allocated to this LP solution assignment.

A final step is performed for each land type after the polygons have been assigned. checking to make sure that all polygons received an allocation and that all allocations are within the user specified fuzzy tolerance. Optionally, on a case by case basis, if the allocation fails to fall within the specified fuzzy tolerance the user can allow the allocation to exceed the automated fuzzy tolerance or fall below it. If the user chooses, a manual allocation can be completed for land types that can not be allocated using automated means.

Mapping Solution Results

After linking the prescription assignment back to the GIS, all forest inputs and outputs created and stored in the RCM can then be summarized and displayed on maps. More complete spatial analysis of the alternative results can also be accomplished through the GIS.